Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**
4. TITLE AND SUBTITLE **HELGA II: Autonomous Passive Detection of Nuclear Weapons Materials**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Chemistry Division,4555 Overlook Avenue SW,Washington,DC,20375**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

HELGA II: Autonomous Passive Detection of Nuclear Weapons Materials

R. August and R. Whitlock
Chemistry Division

Introduction: During the televised debates of the recent presidential election, both candidates listed nuclear nonproliferation as their number one priority. Attempts by rogue nations and terrorist organizations to obtain weapons-grade nuclear materials make the headline news with alarming frequency. Unfortunately, nuclear materials emit little detectable radiation, making it very hard to prevent their being smuggled into this country or to find them once they are here. Most currently available radiation detection systems cannot sort out a nuclear weapon signature from naturally occurring radiation backgrounds with enough certainty and rapidity to interdict it in a realistic smuggling scenario. Consequently, the specter of a nuclear detonation in an American city looms large. Also, the possibility of a nuclear "USNS *Cole* incident" perpetrated on an American fleet far from home should not be ignored. In fact, Albert Einstein spoke of just such an incident in his first letter to President Franklin Roosevelt: "…a single bomb of this type, carried by a boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory."[1]

The Office of Naval Research and the Coast Guard has tasked the Naval Research Laboratory to produce the HELGA II prototype as a step toward addressing this problem. HELGA II is the modernization of HELGA (High Efficiency Large Germanium Array[2]), a national asset developed by NRL in the 1980s to detect faint gamma-ray sources in a natural environment, the same problem faced today when looking for smuggled nuclear materials. NRL, where the detection of nuclear weapons signatures in a natural environment has been studied for more than half a century, is uniquely qualified to produce such a device and to guide its effective use. For example, the U.S. Navy History web site[3] documents NRL's use of nuclear detectors during fly-overs of the Soviet fleet during the Cuban Missile Crisis in 1962.

Detector Requirements: The crux of the problem is that while nuclear weapons materials have unique spectral signatures in the gamma-ray region, a detector with high-energy resolution (selectivity), and high collection efficiency (sensitivity) is required to distinguish these signatures from the spectral signatures of a vast number of items found in the everyday, real-world background. The only detector material currently capable of this is germanium, but this material is expensive to produce and must be cooled to liquid nitrogen temperatures for effective operation. Consequently, nuclear detection systems have typically relied on lesser materials, the best of this class being NaI (sodium iodide). Although NaI has good gamma-ray collection efficiency, it has poor energy resolution, as shown in the Fig. 7. When considering realistic nuclear weapons signatures, NaI can do no better than state a probability that an inspected item might be nuclear weapons material. Germanium can make a positive identification. Real-world interdiction requires positive identification, and therefore requires germanium. In fact, because germanium allows positive identification, it provides a system where the identification can be made instantly by an onboard computer, rather than by waiting for nuclear experts to mull over a spectrum, as required by NaI. The HELGA II prototype was developed to prove that an autonomous identification system based on germanium can be developed and deployed in an affordable fashion.

When the original HELGA system was developed in the 1980s, germanium detectors were delicate laboratory devices that required liquid nitrogen for cooling. The HELGA project ruggedized germanium detectors for field use, but it could do nothing to alleviate the requirement for liquid nitrogen cooling. Nevertheless, HELGA collected interesting real-world data that characterized the capabilities of germanium detectors. Such data go far toward determining how effective germanium can be today at identifying nuclear materials signatures hidden in the real-world background.

Since the 1980s, mechanical coolers have been used with germanium detectors to supplant liquid nitrogen cooling. The HELGA II prototype uses a mechanically cooled germanium crystal for gamma-ray detection. The cooling is accomplished by a Sterling engine that is available commercially. The prototype was built by Canberra Industries. The HELGA II prototype is housed in a footlocker-sized enclosure that isolates it from water and mechanical shock. The prototype is designed to be as close to a commercial product as possible, therefore its peak analysis and identification software is the standard Canberra Industries product. However, like all commercial software, this software produces complex data suitable for analysis by scientists. What is needed is software that produces only the essential information required for

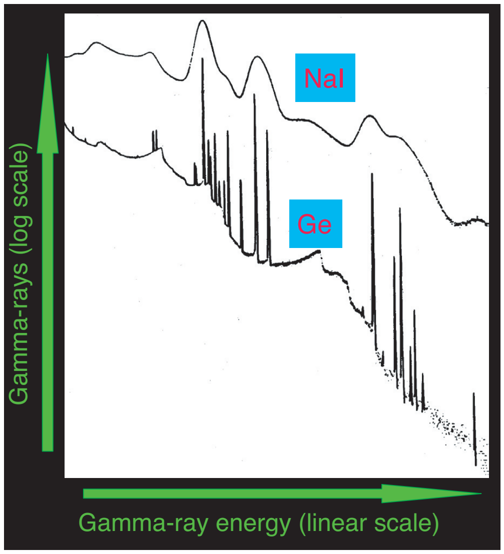

FIGURE 7
NaI and Ge comparative measurement of same multisource target.

Naval operations and implementation by Coast Guard personnel.

NRL Implementation: NRL added custom software that works in concert with the Canberra software to take the scientist out of the decision-making loop in the field. This algorithm takes into account the complexities of past data collected at sea by NRL, as well as the spectral characteristics of nuclear weapons materials and the implications of emerging threats such as clandestine radiation dispersal devices (RDD). Technical issues addressed include the nature of the target to be located and identified, the treatment of natural and anthropogenic backgrounds, shielding considerations, measurement ranges, and dwell times. The final output of the software is a simplified report of what threats, if any, were found. In its final form, HELGA II will be completely autonomous in performing the functions necessary to identify nuclear weapons materials and alert the appropriate personnel.

Possibilities: The HELGA II prototype will demonstrate deployment on a small boat, while paving the way for a large range of alternate deployment options: small and large boats, remotely controlled jet ski platforms, helicopters, and man-portable systems. Such flexible deployment scenarios allow a large range of surveillance options: small HELGA II craft such as boats and jet skis allow a wide zone of control around fleet assets; HELGA II craft of any size allow for covert surveillance of boats and ships; HELGA II buoys at choke points allow continuous surveillance of passing watercraft; man-portable systems allow detailed search and identification in ship boarding scenarios.

[Sponsored by ONR]

References

[1] http://www.anl.gov/Science_and_Technology/History/Anniversary_Frontiers/aetofdr.html, accessed 18 November 2004.
[2] L.A. Beach and G.W. Phillips, "Development of a Rugged HPGe Detector," *Nuc. Instr. Meth. Phys. Res.* **A242** 520-524 (1986).
[3] http://www.history.navy.mil/faqs/faq90-5c.htm, accessed 18 November 2004.